

8. Testing

8.1 INTRODUCTION

Stringent testing is necessary to achieve and maintain the high performance levels required of a high-efficiency nuclear air cleaning system. By definition, such systems must exhibit an installed decontamination factor (DF) of at least 2000, that is, an efficiency of 99.95%, for aerosols having a number median diameter (NMD) less than 1 μm . Decontamination factors near 2000 may be required for gaseous radioiodine compounds. Processes that involve the handling of plutonium and other transuranic elements may require total system DFs of 10^6 or higher. These factors are achieved by providing two or more HEPA filters in series and compare with DFs of only 4 to 6.5 for particles in this size range attainable in most industrial and conventional ventilation air cleaning systems.¹

System tests fall in two broad categories: (1) prestartup acceptance tests which verify that components have been installed properly and without damage, and demonstrate that the system can operate as intended and (2) surveillance tests made periodically after the system has been placed in operation to demonstrate its continuing ability to perform its intended air cleaning function. Surveillance tests are leak tests of the HEPA filter and adsorber installations. Details of major acceptance and surveillance tests, in sufficient detail to provide guidance for the preparation of test procedures, are given in ANSI N510.² In all cases, tests should be preceded by careful visual inspection, as discussed in Sect. 8.4.

8.2 ACCEPTANCE TESTS

Acceptance tests fall into two broad categories: (1) those that relate to the permanent elements of the system, the ducts, housing, mounting frames, and location of test ports, and (2) those that verify the installation and condition of the primary air cleaning

components—HEPA filters and adsorbers. Acceptance tests of HEPA filter and adsorber installations are identical to the surveillance tests of those elements and are covered in Sect. 8.3. Tests in the first category include leak tests of ducts, housings, and primary-component mounting frames; airflow capacity and distribution tests; gas residence time tests for systems containing adsorbers; duct-heater tests for systems containing heaters; and air-test agent mixing-uniformity tests. The acceptance test program for a particular system may contain any or all of these tests, depending on the nature of the system and its importance, that is, the potential consequence of a failure of, leakage from, or release from the system.

Nuclear Regulatory Commission guides recommend the full battery of acceptance tests for ESF systems.³ Lesser systems may not warrant such stringent testing. On the other hand, these tests, which are made only once at the time of acceptance of a new or rebuilt system, provide an assurance of system reliability that cannot be obtained in any other way, and the American National Standards Committee N45-8 (responsible for ANSI N510)² recommends that they be considered for any high-reliability system.

8.2.1 Duct and Housing Leak Tests

The level of duct and housing leaktightness, and therefore the acceptance criterion for the test, is based on the type of construction and the potential hazard (consequence) of a leak. Recommended maximum permissible leak rates for various duct and housing constructions are given in Tables 4.5 (for ducts) and 5.6 (for housings). The designer may specify tighter requirements, based on the containment requirements of the system, but is cautioned against specifying a degree of leaktightness that cannot be met on a practical basis.

Duct leak tests may be made by testing the entire ductwork system at one time or by testing one section

at a time, blanking off the ends of the section under test. The second method is more practical for large systems. When segmented, the permissible leak rate for the individual sections is based on the proportionate volume of that section. The apparatus and procedure for leak testing level 1 and 2 ducts are described in the SMACNA High Velocity Duct Construction Standards.⁴ Test methods for level 3, 4, and 5 ducts and for housings are described in Sect. 6 of ANSI N510.² If the specified leaktightness cannot be met, leaks are located and repaired by one of the methods described in Sect. 6 of ANSI N510 before making the final leak rate test for record. Halogen and mass spectrometer leak-detection methods are generally too sensitive for this application; furthermore, the halogen method introduces a contaminant that may interfere with subsequent in-place testing of adsorbers.

8.2.2 Mounting Frame Leak Tests

These tests are made to verify that there are no leaks through HEPA filter and adsorber mounting frames or through the seal between the mounting frames and the housing. The tests also verify that there is no bypassing of the mounting frames through electrical conduits, drains, compressed air connections, common anterooms of the housing, or other inadvertent leak paths. Familiar sources of leaks are weld cracks and incomplete welds. A properly designed mounting frame should have no penetrations (by conduits, piping, or ducts), and lighting, drain, and other ancillary systems should be designed so that no bypassing of the HEPA filters and adsorbers can occur. Nevertheless, unauthorized modifications are often made in the field. The purpose of this test is to disclose such items as well as leaks caused by poor workmanship or shipping damage. The test is recommended for any installation, whether duct and housing leak tests are made or not, but it is particularly necessary when subsequent in-place tests of the HEPA filter and adsorber stages are to be made by a shrouded method (Sect. 8.3.1).

The test is first made by blanking off all openings for filters and adsorbers, closing or blanking off all openings in the housing, and conducting a soap-bubble or spray-DOP leak test around all welds and other potential leak paths, as described in Sect. 7 of ANSI N510. After all leaks have been repaired, individual chambers of the housing should be checked by a pressure leak rate test to verify that there are no bypasses that have not been disclosed by the leak detection check. It is not necessary that these tests be

made from the upstream side of the mounting frame, and it is quite acceptable to test two mounting frames simultaneously by blanking off the openings of both and pressurizing the space between. Because the mounting-frame-pressure leak test is a chamber-by-chamber test of the housing, it can replace the need for a housing leak test (Sect. 8.2.1).

8.2.3 Airflow Capacity Test

The purpose of this test is to verify that the system of fans, ducts, housings, filters, dampers, and other specified components, as installed, will produce specified airflows under the clean-filter and dust-loaded-filter conditions that the system will encounter in service. Filter resistance should, in nearly all cases, be the only uncontrollable variable in the system, and the system must be capable of producing the design airflow during all stages of normal filter life. Filter resistance will be encountered in pad-type demisters, in prefilters, and in the HEPA filters. There should be no pressure buildup due to dust in adsorbers properly protected by HEPA filters. The allowable resistance increase for demisters and prefilters should be obtained from the manufacturer. The maximum clean-filter pressure drop across a new HEPA filter, at rated airflow, is 1 in.wg or less. Artificial resistance can be added for the second part of the test by blanking off filters until the desired pressure drop is achieved.

Airflow capacity tests should be made in accordance with Sect. 8 of ANSI N510 and Chap. 9 of *Industrial Ventilation*.⁵ Measurements are generally made at a single point in the duct upstream of the filter housing. When flow velocities in various parts of the system are important, additional tests at critical points in the system may be desirable. Capture velocities at hood and duct openings and transport velocities in ducts will vary according to the nature of the material to be conveyed. These velocities are discussed in Sects. 4 and 5, respectively, of *Industrial Ventilation*.⁵

8.2.4 Airflow Distribution Test— Adsorber Residence Time

Maldistribution and stratification of airflow in the housing of a high-efficiency air cleaning system can cause various problems. In demisters, which depend on high velocities and impaction for effective operation, excessive penetration of small droplets may occur in low-velocity areas of the demister bank, whereas reentrainment may occur in areas subject to

higher-than-design velocity. In prefilter and HEPA filter banks, variable distribution of airflow across the bank may result in underutilization of some of the filters and perhaps variable performance. A jet effect has been observed opposite the inlets to some large filter banks, which causes the filters directly in the path of the jet from the housing inlet to become more heavily dust loaded than those not in the path. In some cases, filter damage has been observed in the impacted filters. Variable airflow distribution across a bank of adsorber cells results in high penetration of cells in high-velocity areas, because effective operation for organic radioiodide adsorption is directly related to gas residence time. CS-8 type II (tray)⁶ adsorber cells are designed to produce an average residence time of 0.25 sec when filled with 8- by 16-mesh activated carbon and operated at a volumetric airflow of 333 cfm. The minimum residence time for trapping organic radioiodides is considered to be 0.20 sec. Conformance to the requirements of Sect. 8 of ANSI N510, which permits a variation of +20% from the design airflow at any point of internal components, will ensure that the required residence time can be achieved in any adsorber cell in the bank.

8.2.5 Air-Test Agent Mixing Tests—Testability

No safety credit can be claimed for HEPA filters or adsorbers that are not tested regularly to verify that they continue to meet performance requirements. Although individual filter units and adsorber cells are tested by the manufacturer, in-place testing after installation is essential because of the damage and deterioration that can take place during shipping, handling, installation, and service. Therefore, an important phase of acceptance testing is to verify that HEPA filter and adsorber installations can be tested satisfactorily. The design of many older systems permitted an acceptance test of the HEPA filters, but these designs were such that tests after the system went into operation were nearly impossible, particularly if the system had become contaminated. Such designs are not acceptable in high-reliability applications.

In-place tests are made by introducing a test agent, DOP for HEPA filters and fluorocarbon refrigerant gas for adsorbers, upstream of the bank to be tested. The concentrations of test agent upstream and downstream (upstream concentration is considered 100%) are then determined, and penetration is calculated from the ratio of concentrations. Reliability of the test is determined by (1) the ability to

properly introduce the test agent and to obtain representative samples and (2) physical access to the banks being tested. The first can be verified by an air-aerosol mixing test. This test is made once, at the time of acceptance testing, and its satisfactory completion is a prerequisite to both acceptance and future surveillance in-place testing of HEPA filters and adsorbers.

Good testability requires the provision of permanent test agent injection and sample ports, or other planned and preestablished means for injecting the test agent and for taking reliable, well-mixed samples. Details of the air-aerosol mixing test are described in Sect. 9 of ANSI N510.² It is essential that the air and test agent mixture charged to the filters (adsorbers) is thoroughly mixed so that concentrations entering all points of the filters, including the upstream and downstream sample points, are essentially uniform. Adequate mixing upstream usually can be obtained by introducing the test agent at least 10 duct diameters upstream of the filters or adsorbers, or by introducing it upstream of baffles or turning vanes in the duct. When neither of these methods is practicable, a Stairmand disk⁷ located 4 to 6 duct diameters upstream will give satisfactory mixing. When duct arrangement makes it necessary to introduce the test agent directly into the filter housing, a design such as that discussed under multistage housings (Sect. 8.3.3) may be required. Extraction of the downstream sample at a point several duct diameters downstream of the fan will usually provide a well-mixed sample. Fan-shaft leakage is a consideration in sampling downstream of the fan. Since leakage at the shaft will be inleakage, sufficient air to excessively dilute the downstream sample can be drawn in if the shaft annulus is large (thus giving a low downstream concentration reading), or dust may be drawn into the fan which will provide a high downstream reading (which may be particularly prevalent during construction). A shaft seal, or at least a temporary seal to be applied during testing, is recommended.

The second aspect of testability, access, requires space for personnel and equipment; space to manipulate equipment without damaging filters or creating hazards for personnel; passages for getting personnel and equipment to the point they are needed; provision for getting services (electrical, compressed air) to the equipment; access to both faces of filters and adsorbers; adequate lighting; viewports; and other features that facilitate safe

testing. These testability requirements are all matters of design that should be checked before the start of construction, and they should be confirmed as part of the acceptance check. The space, access provisions, service galleries, and filter-array recommendations of Chap. 4 are essential for effective in-place testing in man-entry housings. Lights should be provided between each chamber of the housing (space between banks or between bank and end wall) and should be sufficient to produce a light intensity of at least 5 ft-c, and preferably twice that value, on the faces of the filters and adsorbers. Reliance on flashlights and portable lamps is a hazard that should be avoided in man-entry housings; either can be dropped, leaving the workman in the dark and under adverse conditions. A portable light usually gives too little light to be useful, and if dropped from a service gallery, is a danger to workmen below. Also, a drop cord is an additional hindrance in what is often an already too-crowded working space.

Switches for permanent lights should be installed on the outside of the housing, adjacent to the door of the illuminated chamber. Thus when viewports are provided the filters can be checked without entering the contaminated housing. Figure 8.1 illustrates the advantage of viewports when sufficient internal lighting is provided, whereas Figs. 8.2 and 8.3 illustrate the problems encountered by service personnel in poorly designed, poorly laid out, and poorly lighted housings. In Fig. 8.2, there is no possible access to the upper two tiers of filters without bringing ladders or scaffolding into the housing, a hazard to installed filters and to personnel.⁸ The layout in Fig. 8.3 is not only hazardous to personnel from the standpoint of very limited working space but also because of the thoughtless placement of the piping element just above the service gallery floor. Effective testability also demands a limit on bank size from the standpoints of generating sufficient test agent and the time required to test a single bank of

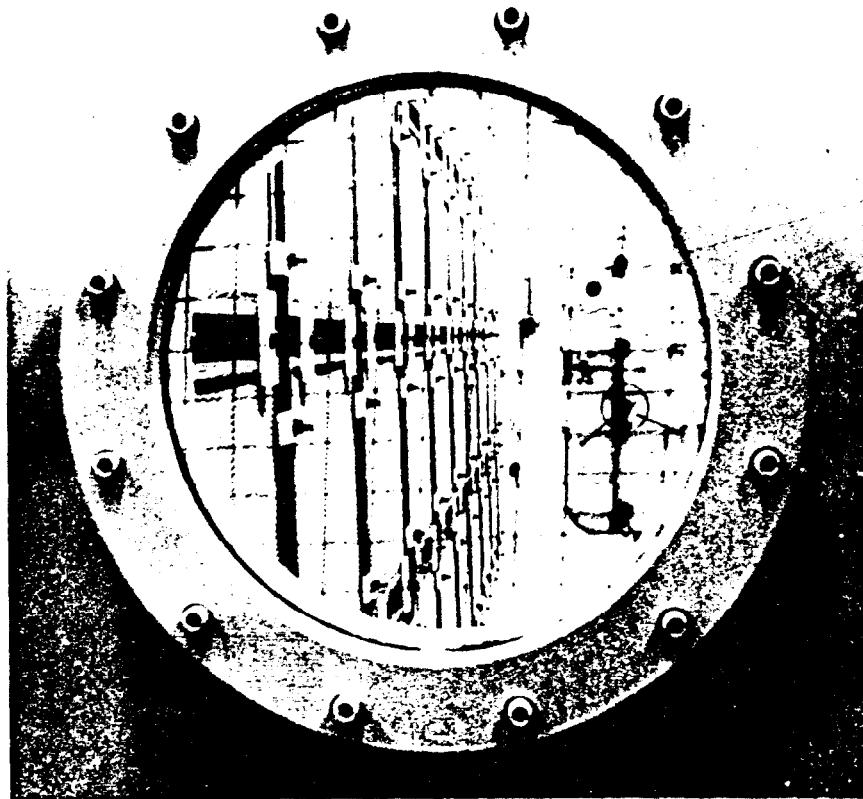


Fig. 8.1. Housing viewport. Note excellent lighting within the housing. Courtesy Rockwell International, Rocky Flats Plant.



Fig. 8.2. Excessively high filter bank. Note that temporary ladders or scaffolding would be necessary to gain access to the two upper tiers of filters.

filters or adsorbers. A limit of 30,000 cfm installed capacity is recommended.^{3,8} Electrical and compressed-air connections should be provided close to but not inside the housing, and provision should be made for bringing cables and air lines (when required for testing) into the housing without going through the door. A cable chase can be made by drilling a hole through the housing wall and welding a 2- to 3-in. half nipple on the outside; the nipple is capped (using fluorocarbon tape to prevent galling) when not in use (such passthroughs should be included in the original design). Chapter 4 recommends door latches operable from both sides in man-entry housings; these latches are essential to prevent personnel from being trapped inside. If a fan is located inside the housing, guards must be provided on its inlet, belts, and shaft extensions. Finally, testability demands preplanned, written test procedures that have been carefully reviewed and checked as part of the acceptance program.

8.3 SURVEILLANCE TESTING

Surveillance tests are of three types: in-place leak tests of HEPA filter stages using DOP, in-place leak tests of adsorber stages using a slightly adsorbable gas such as fluorocarbon refrigerant-11 (R-11), and laboratory tests of samples of adsorbent withdrawn from the system to establish its remaining adsorption capacity. These tests are also employed as part of the acceptance procedure for new installations, except that laboratory tests are made on samples of adsorbent taken from batch material as furnished.

Surveillance tests of HEPA filter and adsorber systems should be made at regular intervals after installation to detect deterioration and leaks that may develop under service conditions. Regular in-place



PERMANENT SERVICE GALLERY

Fig. 8.3. Inadequate space between banks of components. Note stumbling hazard on floor of service gallery.

testing of standby systems is necessary because deterioration can take place even when systems are not being operated. Aside from component damage, frequently discovered causes of failure to meet in-place test requirements include loose clamping bolts, inadequate clamping devices, foreign material trapped between gaskets and mounting frame, rough or warped mounting-frame surfaces, cracked welds, unwelded joints in mounting frames, incorrectly installed components (e.g., HEPA filters installed with horizontal pleats), inadequate seals between mounting frame and housing, poorly designed mounting frames, and bypassing through or around conduits, ducts, or pipes that penetrate or bypass the mounting frames. Tests of 50 HEPA filter banks at one ERDA installation, prior to initiating a routine testing program, revealed 31 banks (62%) that could not meet the maximum system penetration of 0.05%.⁹ After repair or rebuilding of the unsatisfactory banks, they have routinely exhibited penetrations

within specified values; of some 670 HEPA filter installations at Oak Ridge National Laboratory, most routinely exhibit penetrations of less than 0.008%.¹⁰

8.3.1 In-Place Testing for HEPA Filters

In-place tests of HEPA filter installations are made with an aerosol of polydispersed DOP consisting of droplets having a light-scattering NMD of $0.7\ \mu\text{m}$ and a size range of approximately 0.1 to $3.0\ \mu\text{m}$.¹¹ The DOP used for efficiency testing by manufacturers and ERDA Quality Assurance Stations is a monodispersed aerosol having an NMD of $0.3 \pm 0.03\ \mu\text{m}$. The in-place test is made by charging the upstream side of the filter or filter bank with DOP smoke, then measuring and comparing (using a light-scattering photometer) the DOP concentration in samples of filtered and unfiltered air (Fig. 8.4). If the

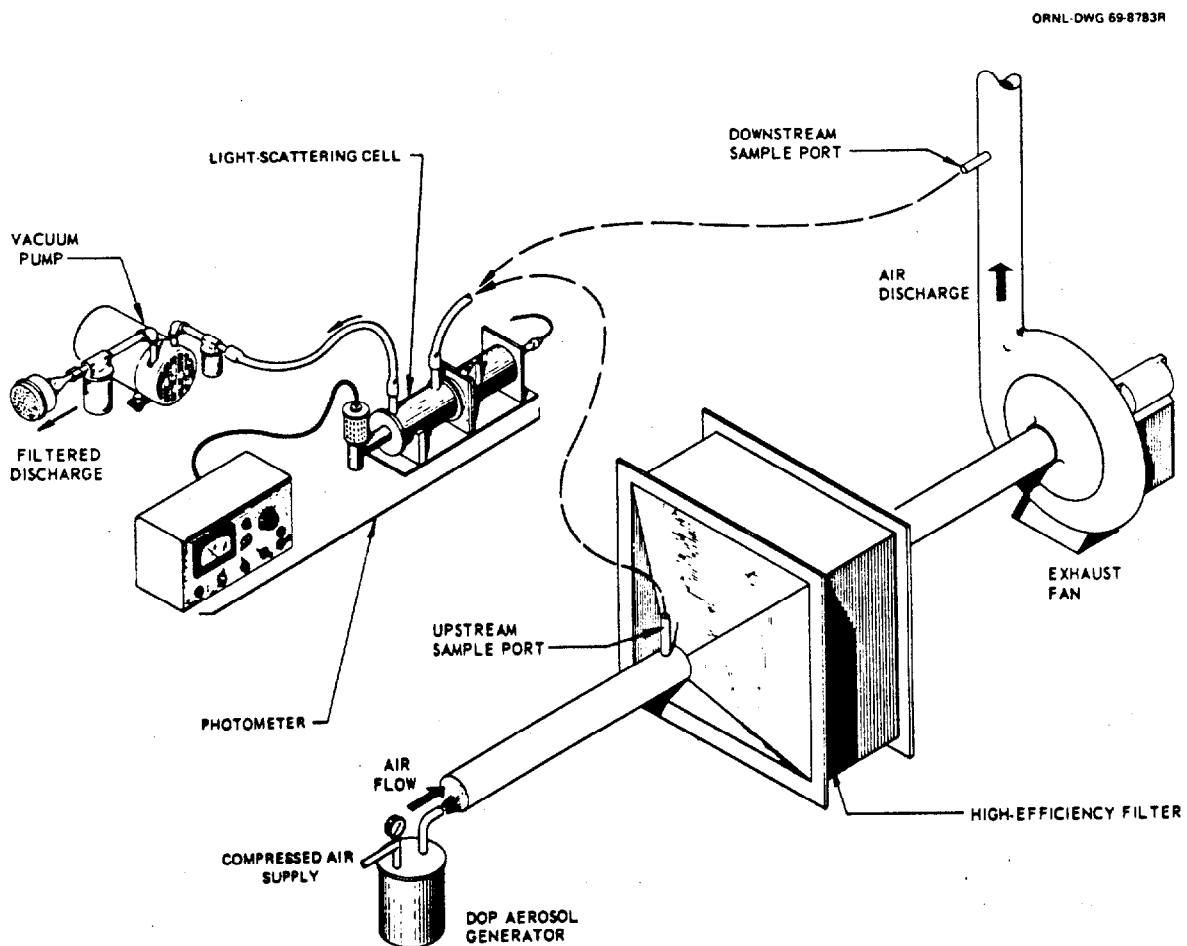


Fig. 8.4. Equipment arrangement, in-place test of HEPA filters.

system exceeds the specified maximum permissible penetration value, the downstream faces of the filters and mounting frame can be scanned with the photometer probe to locate localized high DOP concentrations which indicate leaks.

Figure 8.4 shows basic equipment and a schematic of a typical test arrangement. The instrument shown is the Naval Research Laboratory (NRL) linear readout, forward-light-scattering photometer. An instrument having a threshold sensitivity of at least 10^{-3} $\mu\text{g/liter}$ for 0.2- to 1.0- μm particles and a sampling rate of at least 1 cfm is recommended.¹¹ The instrument should be capable of measuring concentrations 10^5 times the threshold value. Compact self-contained instrument packages are commercially available (Fig. 8.5). Polydispersed DOP aerosol may be generated thermally¹² or by compressed air. Compressed-air generators are widely used for testing small systems. They are commercially available or can be homemade in sizes from 1 to 24 nozzles. Figure 8.6 shows details of a six-element Laskin-nozzle generator installed in a paint bucket. A rule of thumb for determining generator capacity is to allow one Laskin nozzle per 500 cfm of installed filter capacity. Compressed-air DOP generators are suitable for systems up to about 3000 cfm; above this size they become cumbersome.⁸ Although gas-thermal generators are generally used for testing systems of 20,000 cfm installed capacity and larger, they have too much output for small systems (Fig. 8.7). The engineer must not confuse this type of

generator with the equipment used by manufacturers or ERDA Quality Assurance Stations for predelivery efficiency testing of HEPA filters (Fig. 8.8). The gas-thermal generator produces a polydispersed aerosol of about the same NMD and size range as the compressed-air generator. It is small and can generally produce enough aerosol at a concentration of 80 to 100 $\mu\text{g DOP/liter}$ to test banks up to 30,000 cfm installed capacity. Gas-thermal generators capable of producing enough aerosol to test a system of 200,000 cfm installed capacity at a concentration of 40 $\mu\text{g DOP/liter}$ are said to be commercially available.¹³

A detailed description of the procedure for conducting an in-place test of HEPA filters is given in Sect. 10 of ANSI N510.² Prerequisite to the test is the demonstrated ability to achieve good mixing of the DOP and air at the upstream and downstream sample points (Sect. 9, ANSI N510). For systems in which good mixing cannot be achieved, multipoint sampling and averaging, in accordance with Sect. 11 of ANSI N510, may be used. Figure 8.9 shows a well-planned test-port installation. Figure 8.10 illustrates the type of improvisations the operator may have to resort to when the designer fails to take testing into consideration in the original layout of the system.

For installations designed in accordance with this handbook and employing HEPA filters that have been tested by one of the ERDA Quality Assurance Stations, an acceptance criterion of 0.03% maximum penetration is recommended for the in-place DOP test. This value is equivalent to the minimum

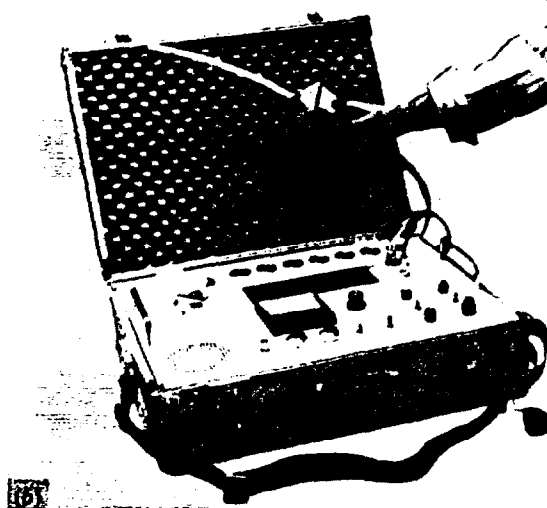
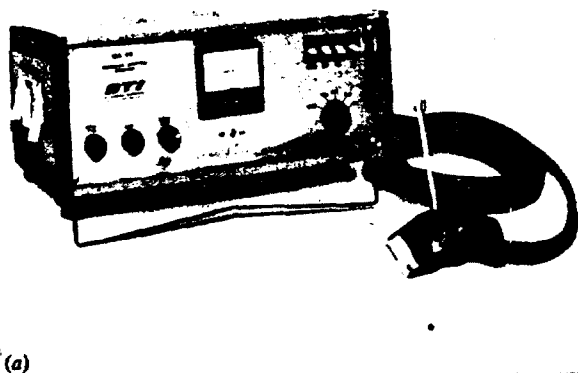


Fig. 8.5. Commercially available packaged forward-light-scattering instruments for HEPA filter testing. (a) Air Techniques, Inc., Model TDA-2D; (b) Frontier Enterprises, Inc., Model FE973.

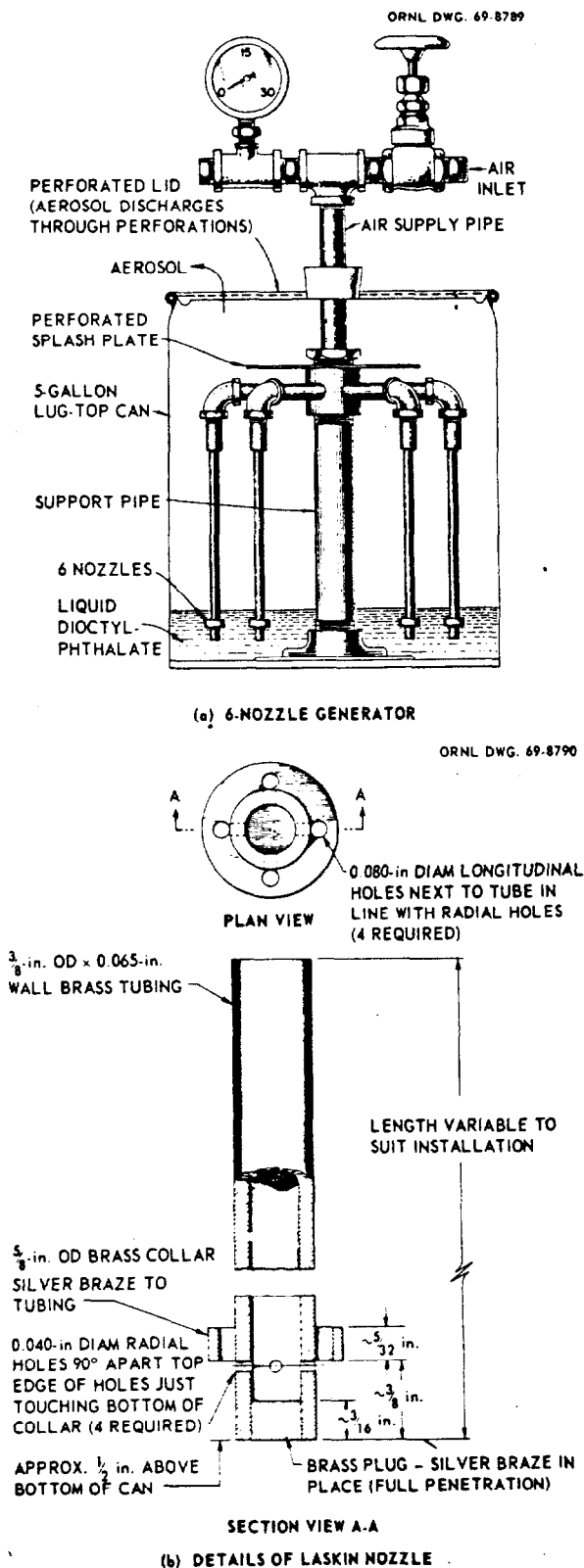


Fig. 8.6. Compressed-air-operated DOP aerosol generator.

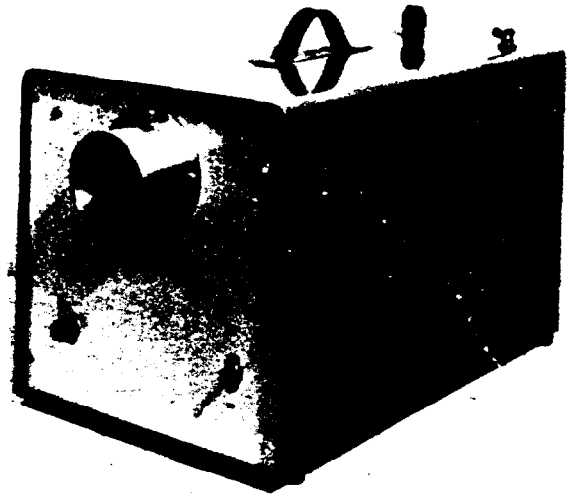


Fig. 8.7. Gas-thermal DOP generator for in-place testing of HEPA filter systems. Generator produces a polydispersed smoke of approximately 0.7 NMD.

efficiency of new filters. A lesser criterion (0.05%) is allowed for nuclear power plants² and most older installations. However, tests by an ERDA contractor show that the latter penetration can be met in a 20,000-cfm system despite a hole in one of the filters nearly 1 in. in diameter.¹⁴ Experience in repeated surveillance tests of nearly 1000 individual filter systems at another ERDA facility indicates that a properly designed HEPA filter system can routinely meet an acceptance criterion as low as 0.01% penetration.¹⁵ Most HEPA filters tested by the ERDA Quality Assurance Stations now exhibit penetrations in the 0.01% or lower range.¹⁶

The in-place test can be made at rated system airflow or at reduced flow. Because diffusion is the primary mechanism of small-particle collection, the test at reduced flow is often more sensitive than the full test. The actual rate of airflow for the reduced flow test is a function of the sensitivity of the photometer; some test agencies test at as low as 5 to 10% of rated system airflow. Reduced flow testing also has the advantage that less DOP is required.

8.3.2 In-Place Testing for Adsorbers

The effectiveness of an adsorber can be impaired by poisoning (i.e., adsorption of or chemical reaction with paint fumes, solvent vapors, hydrocarbons, and many chemical fumes); by wetting; by settling of the adsorbent in the bed due to vibration or air pulsation; and by design and installation defects. There are two basic methods of in-place testing adsorber systems.

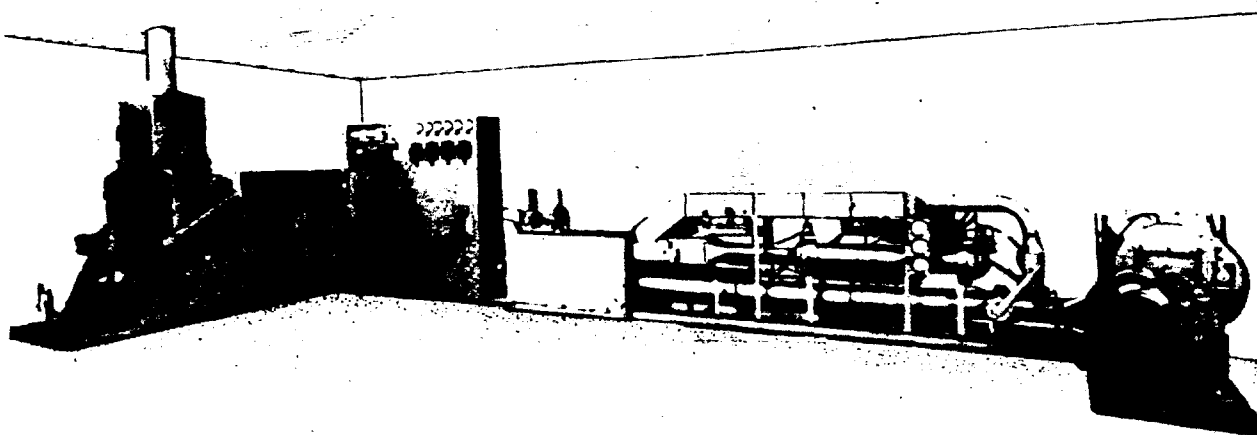


Fig. 8.8. U.S. Army Q-107 penetrometer for efficiency testing of HEPA filters. Equipment contains a thermal DOP generator capable of producing a monodispersed aerosol.

One method uses a fluorocarbon refrigerant gas and the other uses a radioactive tracer gas (iodine or methyl iodide). The first, developed by the Savannah River Laboratory,¹⁷ is the most commonly used, particularly in commercial applications. The second method involves the use of radioactive isotopes and personnel licensed to handle them. Radioiodine tracer methods were developed primarily for ERDA installations.^{18,19} Both in-place tests are leak tests rather than efficiency tests, and they must be supplemented with laboratory tests of samples taken from the adsorbers at the time of the in-place test to determine system efficiency and remaining capacity for iodine. Maximum penetration in the test is based on bed depth and the location of the adsorber.³ For adsorbers designed to operate inside the primary containment of a reactor, permissible penetration is 0.1%, regardless of bed depth. For systems located outside such containment, the maximum permissible penetration is 0.1% for 2-in.-thick beds and 0.05% for thicker beds.

Refrigerant Gas Test. The first test, commonly referred to as the Freon²⁰ test, is made by charging the upstream side of the adsorber with a slightly adsorbable and readily desorbed fluorocarbon gas (usually R-11, trichloro[mono] fluoromethane), and then determining the concentrations immediately upstream and at a point downstream where satisfactory mixing with the air occurs. Penetration is calculated from the ratio of downstream to upstream readings. Refrigerant-112 was originally used but is no longer made. The sampling system consists of a pump to draw upstream and downstream air samples from the

adsorber system, two identical gas chromatographs with electron-capture detectors for measuring refrigerant gas concentrations, a timer, and several rotameters for determining sample dilution factors. The chromatographs should have a linear range of about 1 to 100 ppb (by volume) for detection of the refrigerant gas. Since the upstream concentration exceeds the linear range of the instrument, the sample must be diluted with a known volume of air to bring it within the detection range of the chromatograph. Calibrated rotameters are used to determine the dilution factors. Some organizations combine equipment for adsorber testing with DOP equipment used for testing filters. The equipment used for adsorber and DOP tests is shown in Fig. 8.11. Figure 8.12 shows a schematic of the test setup. Prefilters and HEPA filters in the duct have no effect on the Freon test. The test is relatively easy to conduct by persons experienced in the use of the gas chromatograph, but it must be conducted in accordance with prescribed procedures (Sect. 12, ANSI N510).² Precise adjustment of the airflow rate, the R-11 injection rate, and the chromatographs is not required, but the cross calibration of the two chromatographs is necessary for accurate results. The use of the mixer shown in Fig. 8.12 is not necessary if samples can be taken far enough downstream (approximately 10 duct diameters) to ensure good mixing. Where good mixing cannot be achieved, a multiple sampling technique must be used (Sect. 11, ANSI N510).²

One problem in the use of chromatographs is the instrument's sensitivity to oxygen and to oxygen-containing compounds such as CO₂. Also, the

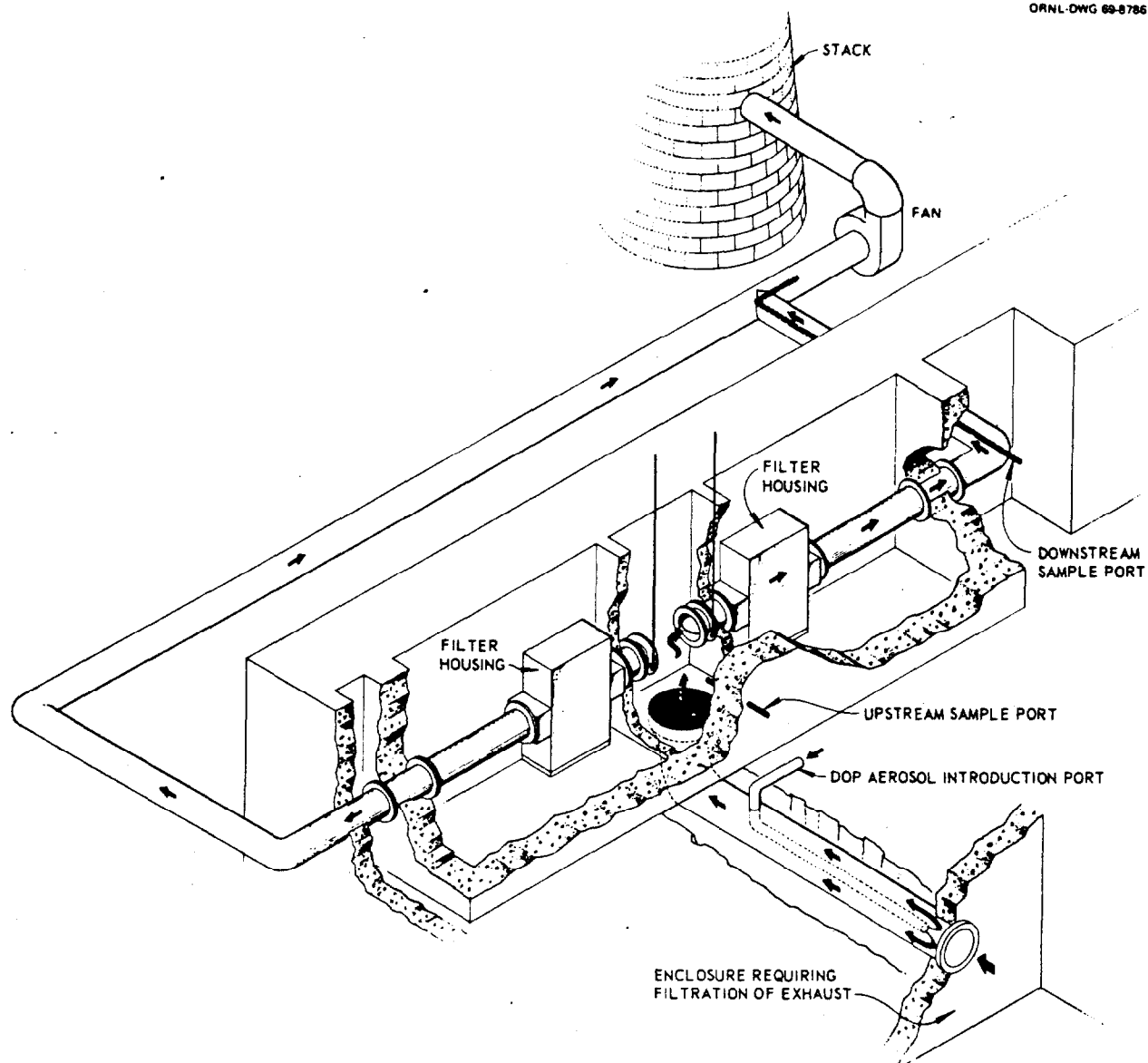


Fig. 8.9. Preplanned arrangement for testing filters in a large laboratory facility.

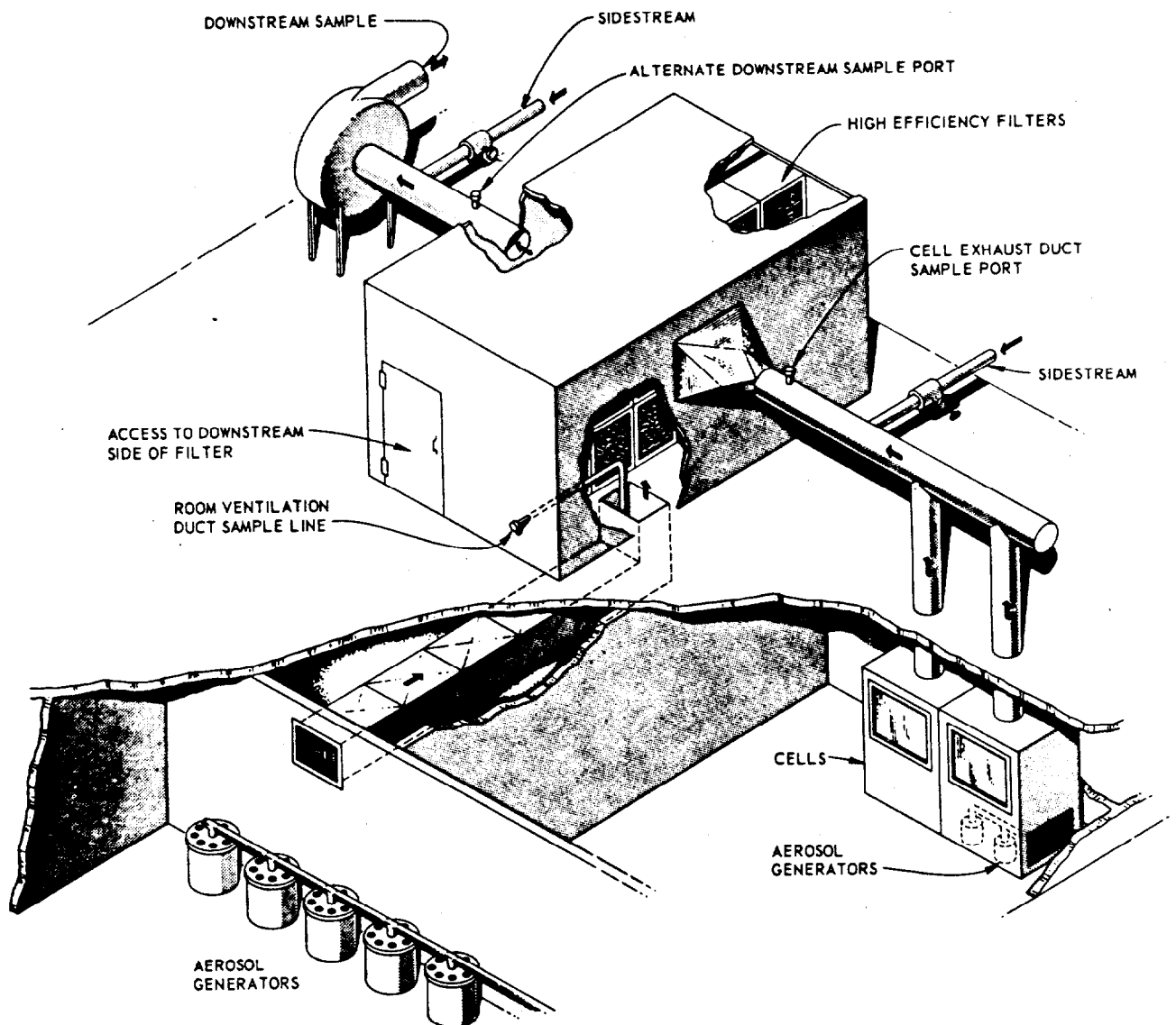


Fig. 8.10. Improvised arrangement for testing filters. No plan for surveillance testing was considered in the original system design. Aerosol generator capacity in cells and room must be balanced to obtain reasonable uniformity of air and DOP in the filter housing

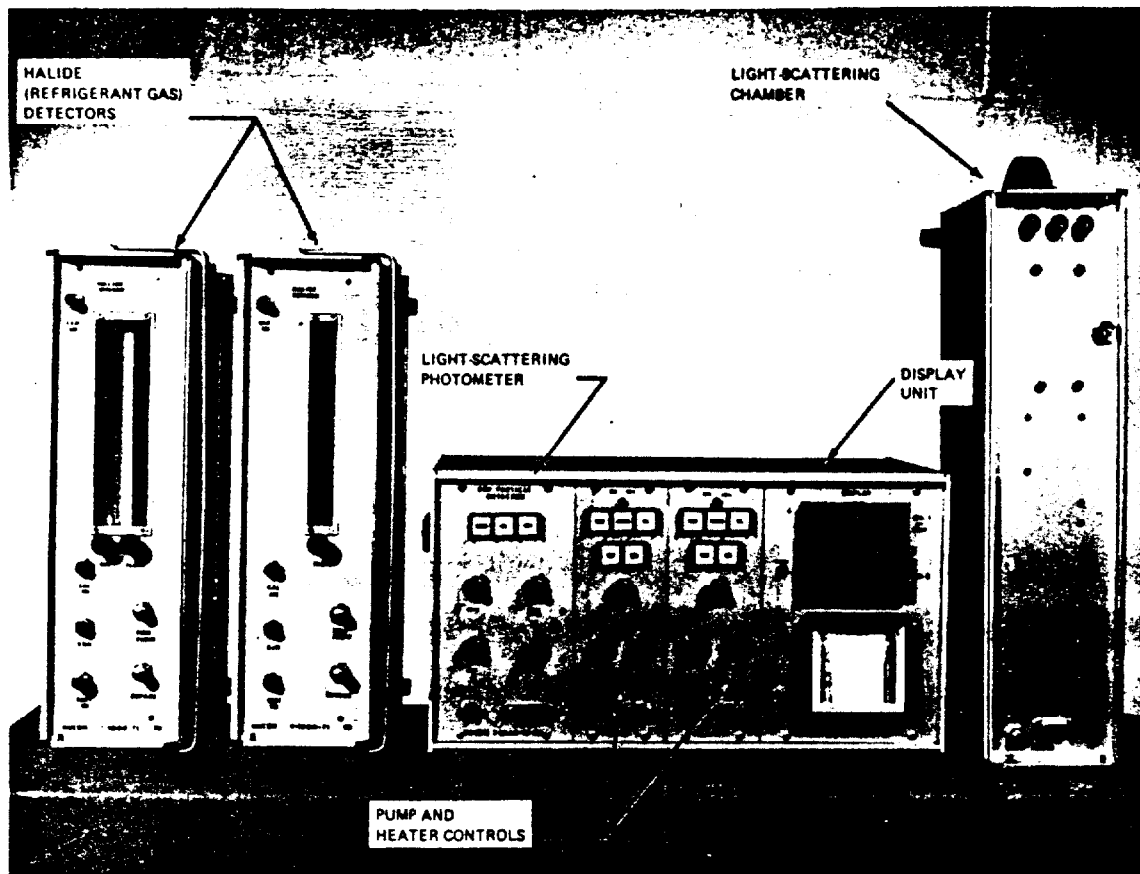


Fig. 8.11. Test equipment for Freon and DOP tests. Courtesy Nuclear Consulting Service, Inc.

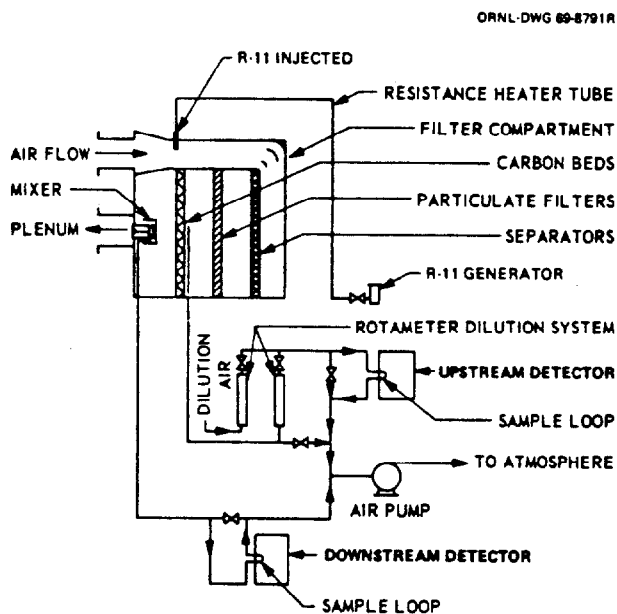
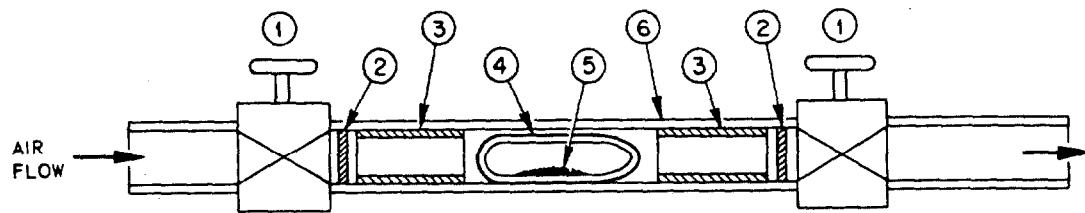


Fig. 8.12. Schematic of Freon (R-11) test arrangement.

accuracy of the test depends on the operator's skill in interpreting peaks on the chromatograph output.

Radioactive Iodine Tests. These tests are currently used for routine adsorber-bank testing at Oak Ridge National Laboratory (ORNL) and the Hanford (Richland, Washington) facilities of ERDA. Two tests are used, one with radioactively traced elemental iodine and the second with radioactively traced methyl iodide. Equipment requirements for the elemental iodine test include an iodine injection tube (Fig. 8.13), two sampling units (Fig. 8.14), a sample extraction pump, and three calibrated rotameters for controlling the injection and sampling flows. The sampling units are filled with charcoal of known efficiency for elemental iodine. The test aerosol is $^{127}\text{I}_2$ containing $^{131}\text{I}_2$ tracer. A combination of injected radioactivity (in microcuries), sampling rate, and counting technique (usually dictated by the kind of counting equipment available) must be developed to give the required test precision. At ORNL, a combination of sampling and injection rates is selected

ORNL DWG. 69-8792

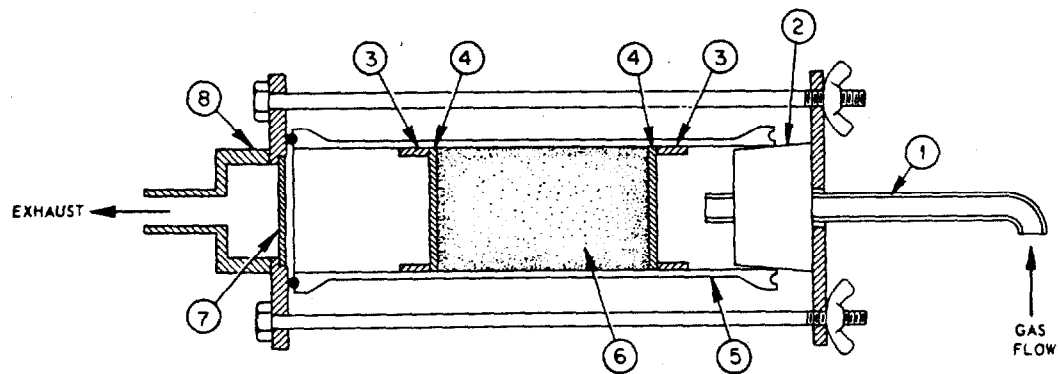


KEY

- 1 VALVE, SEMI-NEEDLE
- 2 WIRE SCREEN
- 3 SPACER, GLASS TUBE
- 4 IODINE AMPUL, GLASS
- 5 IODINE CRYSTALS
- 6 TUBING, STAINLESS STEEL

Fig. 8.13. Injector tube for radioiodine tracer test.

ORNL DWG 69-8793R



KEY

- 1 STAINLESS STEEL PROBE, $\frac{1}{2}$ in. x 12 in.
- 2 STOPPER
- 3 FLEXIBLE BAND RETAINER
- 4 SCREEN
- 5 GLASS PIPE, 2 in. ID
- 6 ACTIVATED CHARCOAL
- 7 HIGH-EFFICIENCY FILTER
- 8 END PIECE AND FILTER HOLDER

Fig. 8.14. Sampling element for radioiodine tracer test.

which, with available counting equipment, will produce an upstream sampler radioactivity count between 8×10^5 and 5×10^6 counts/min. These are not rigid limits but are convenient target values which have considerable latitude. Satisfactory tests have been made at sampling rates as low as 0.03% of the system flow rate, but sampling rates of about 1 cfm per 1000 cfm (0.1%) of rated adsorber capacity are recommended.

The amount of iodine required and the size of the injector tube are not critical. The amount of $^{127}\text{I}_2$ is invariably 100 mg in the ORNL tests, although this amount may be doubled if excessive plateout in the upstream duct or housing occurs. The amount of $^{131}\text{I}_2$ tracer must be adjusted to give the radioactivity count noted above. The radioactive iodine source is prepared by mixing the required quantities of ^{127}I and ^{131}I as NaI, precipitating the iodine fraction as PdI_2 by treatment with acidified PdCl_2 , then decomposing the PdI_2 under vacuum. The liberated $^{127+131}\text{I}_2$ is collected in a liquid-nitrogen-cooled U-tube and transferred to a glass ampule that is installed in the injector. (Fig. 8.13). Preparation of the iodine and loading of the injector must be carried out in a laboratory equipped for handling radioactive materials. To inject iodine during the test, the injector tube is crushed, breaking the ampule and releasing the iodine vapor. Compressed air is passed through the tube at a carefully controlled rate for about 2 hr. During the final half hour, heat is applied to the injection tube to drive out the remaining iodine.

Figure 8.15 shows a typical in-place radioiodine-tracer test setup. After system flow and background

radioactivity levels are established, iodine is injected far enough upstream to ensure adequate mixing with the main airstream, and samples are withdrawn simultaneously through the upstream and downstream sampling units. The injection of iodine is continued for approximately 2 hr, but system airflow and downstream sampling are continued for another 2 hr to catch any iodine that may desorb from the beds, in addition to that which penetrates immediately. Exhaust air from the sampling units is usually dumped back into the upstream side of the main system.

The iodine content of the carbon in the samplers is determined by direct gamma spectroscopy, and the efficiency is determined from the equation

$$E = \left(1 - \frac{C_d}{C_u - B} \right), \quad (8.1)$$

where

E = efficiency, %;

C_d = iodine content of downstream unit, dis/min;

C_u = iodine content of upstream unit, dis/min;

B = background due to impurity iodine in charcoal, dis/min.

The methyl iodide test for determining the efficiency of adsorbents for organic radioiodine compounds is similar to the test for elemental iodine and uses the same equipment except for the injector. The injector used for the methyl iodide test is a U-tube and vapor expansion chamber. Sampling and analytical procedures are the same as those for the elemental iodine test. The test vapor is $\text{CH}_3^{127}\text{I}$ containing $\text{CH}_3^{131}\text{I}$ tracer. Because the methyl iodide test determines a different property of the adsorbent and is dependent on a different sorption mechanism, it cannot be used in place of the elemental iodine test, and both tests are required for a complete evaluation of impregnated charcoal adsorbents. Both of these tests suffer from the limitations of using radioactive tracers in the field and from the number of variables that must be controlled to achieve reliable results.

8.3.3 In-Place Testing for Multistage Systems

Systems that contain two or more HEPA filter stages and/or two or more adsorber stages in series in the same housing give special problems because of the difficulty of obtaining a representative single-point sample downstream of the first bank and the difficulty of introducing the second-stage test agent at a

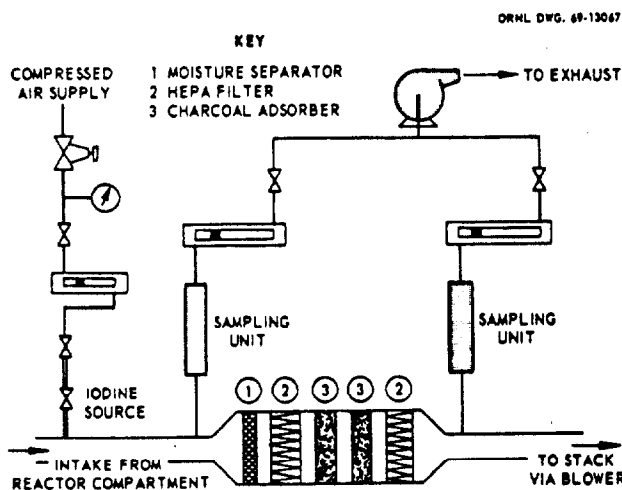


Fig. 8.15. Test setup for radioiodine tracer tests.

point where good mixing can be achieved. Series banks are usually so close that neither of these objectives can be achieved in the normal manner. Because of the very high collection efficiency of the first-stage elements, sufficient test agent cannot be introduced upstream of the first stage to permit effective testing of the second stage. It has been shown that DOP has no adverse effect on activated carbon or other adsorbents when used for testing nuclear air cleaning systems,²¹ and the refrigerant gases used to date have no adverse effect on HEPA filters.

First-Stage Downstream Sample. The first-stage downstream sample can be obtained either by a multiple sampling technique (Sect. 11, ANSI N510) or by providing a temporary jumper duct to bypass airflow around the second stage to either the system fan, as Fig. 8.16 shows, or to a temporary auxiliary fan. In the arrangement shown in Fig. 8.16, the downstream housing damper is closed so that no air is brought through the components downstream of the bypass connection. The downstream sample can be taken either upstream of the fan, in the temporary bypass duct (if that duct is long enough to ensure good mixing), or downstream of the fan. Note that the bypass duct ports must be capped and sealed when not in use.

For testing multistage HEPA filter banks, one ERDA facility scans the downstream face of the stage to be tested in accordance with the procedure outlined in Sect. 4 of IES CS-2.¹¹ The recommended scanning pattern for each filter in the bank is shown in Fig. 8.17.¹⁴ Prior to the start of scanning, the upstream side of the stage is flooded with DOP and the photometer is adjusted to read 100% at full-scale reading on the least-sensitive scale of the instrument. A high concentration will always exist directly downstream of a leak. During the downstream scan, the relative magnitude of each leak is determined by turning the scale shift knob of the instrument until a reading about halfway between half scale and full scale is obtained. The reading is recorded and the leak flow for that point is calculated from the equation

$$\frac{\text{leak-probe meter reading, \%}}{\text{upstream concentration, \%}}$$

$$\times \text{probe flow rate} = \text{leak flow,} \quad (8.2)$$

where probe flow is the airflow capacity of the instrument. The percent penetration of the total bank is calculated from the equation

$$\text{penetration} = \frac{\sum_n \text{leak flows}}{\text{total flow}} \quad (8.3)$$

Defective filters are replaced and installation deficiencies are corrected before making the final test. This method is said to be more sensitive than the usual method of HEPA filter testing, and it is recommended for multistage systems having plutonium or transuranic-element source terms.¹⁴

Test Agent Injection, Second-Stage Upstream Sample. Figure 8.16 shows how a temporary auxiliary duct may be used to introduce a test agent to a multistage system. This figure shows the DOP being injected for a first-stage filter test; however, a similar method can be used to introduce a test agent into the space between the first and second stages. For the second stage, the downstream damper of the housing is opened and the system fan draws directly through the bank under test. If for some reason the system fan cannot be used, an auxiliary fan may be used to establish airflow, as shown in Fig. 8.18.

When the test agent is introduced through an auxiliary duct (Fig. 8.16), the upstream sample can be taken any place in the auxiliary duct (upstream of the bank to be tested), assuming that the auxiliary duct is long enough to ensure good mixing. When using an auxiliary blower, a downstream sample can be taken downstream of the blower, as shown in Fig. 8.18.

Another method of obtaining proper mixing of test agent with air is to shroud adjacent filters (adsorbers) and introduce the agent to each filter element (adsorber cell) individually by using a multiple discharge distributor, as shown in Fig. 8.19. The upstream sample is taken downstream of the perforated distribution plate. The downstream sample is taken with a multipoint sampling probe (Fig. 8.20). The penetrations of the individual filters (adsorbers) are averaged to find the gross bank penetration. This method requires that a mounting-frame pressure leak test be made, usually at the time of acceptance testing,⁸ and that air containing test agent be passed through one unit (filter or adsorber cell) or group of units one at a time. The method has the advantage of substantially reducing the total quantity of test agent

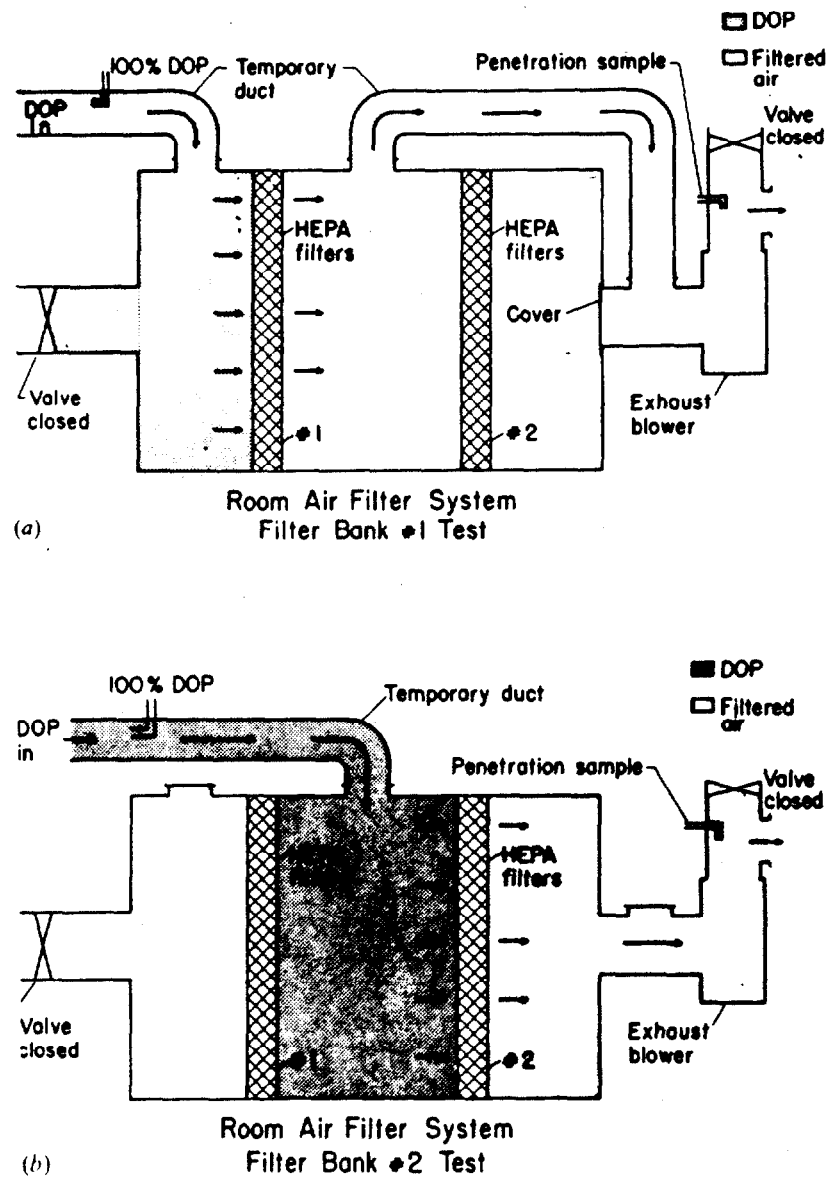
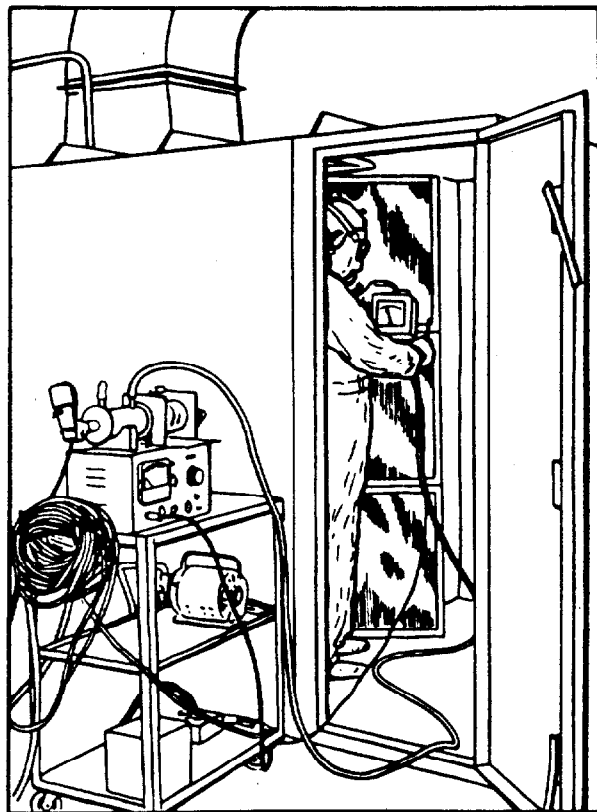
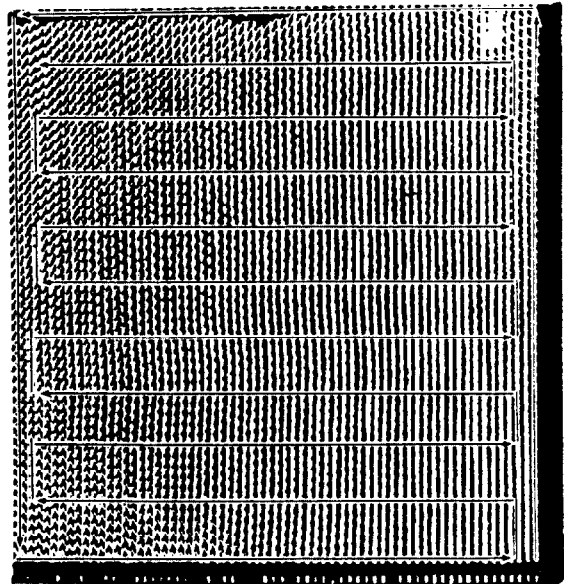


Fig. 8.16. Testing of multistage HEPA filter installation, permitting individual testing of each bank. Test can be made using an auxiliary blower, at reduced flow, instead of the system fan (see Fig. 8.18). (a) Test setup for testing upstream bank of filters. DOP generator located at entrance to temporary duct on right. Temporary duct on left provides bypass of second-stage filters to system fan. (b) Test setup for testing downstream bank of filters. DOP generator located at entrance to temporary duct; no bypass duct required. From R. Mitchell et al., "Design of Ventilation and Air Cleaning Systems for the New Los Alamos Plutonium Facility," *Proc. 13th AEC Air Clean. Conf.*, ERDA Report CONF-740807, March 1975.

ORNL DWG. 69-8788



(a)



(b)

Fig. 8.17. Scanning HEPA filters to locate leaks. (a) Leak probing HEPA filter bank; extension meter used to measure a sharp increase in DOP, which would indicate a leak; (b) suggested probe-scanning pattern for 24- by 24-in. HEPA filter.

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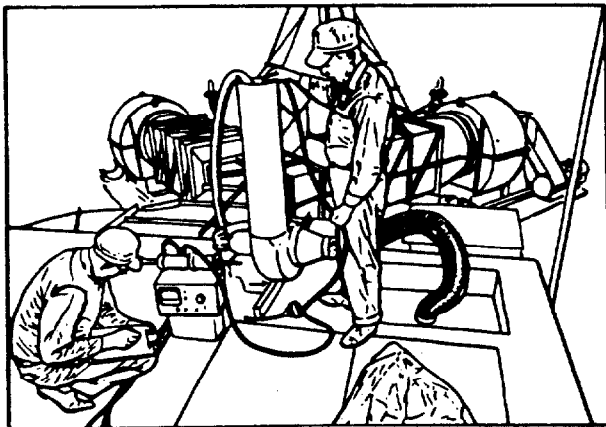


Fig. 8.18. Auxiliary blower being used for testing first-stage HEPA filter bank in a 15,000-cfm air cleaning system. DOP is injected in duct upstream of housing, and air is extracted between bank of adsorbers and second stage of HEPA filters. Downstream sample is taken in stack of auxiliary blower.

introduced to the system if scanning is required to locate leaks; however, it requires more time than the usual method of taking single-point upstream and downstream samples.

Because DOP has no adverse effect on activated carbon and refrigerant gases have no adverse effect on HEPA filters, it is possible to inject DOP upstream of the adsorbers when testing a second-stage HEPA filter bank and to inject refrigerant gas upstream of the HEPA filters when testing adsorbers.

8.3.4 Adsorbent Sampling and Testing

For licensed reactors, laboratory tests of adsorbent should be made in accordance with the performance (iodine) test requirements of RDT M16-1²² and should meet the acceptance criteria given in Table 8.1. Laboratory testing is costly and is usually kept to a minimum. Samples taken for testing must be as

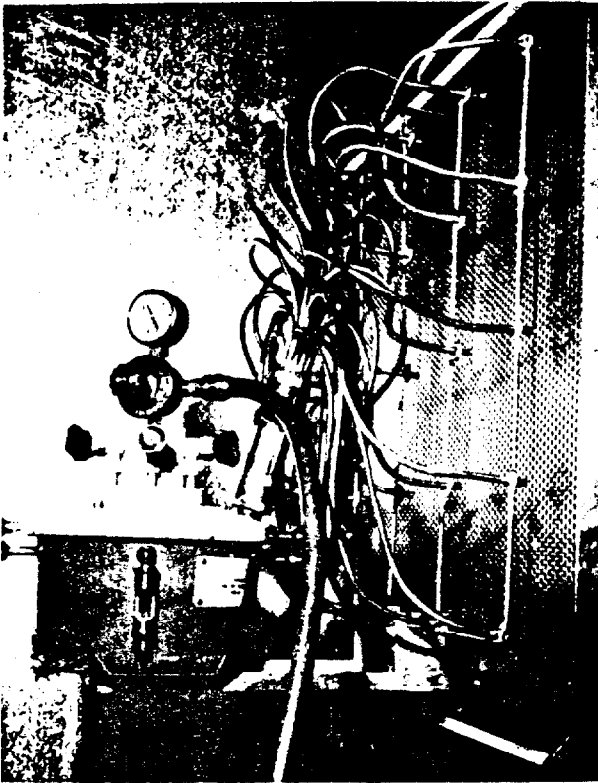


Fig. 8.19. DOP smoke distributor mounted in temporary shroud. Courtesy American Air Filter Co.

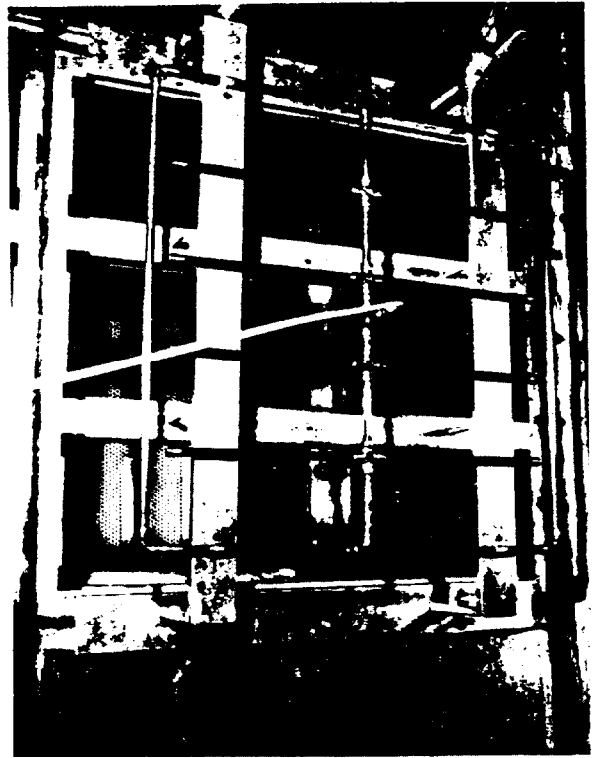


Fig. 8.20. Multipoint sampling probe. Courtesy American Air Filter Co.

Table 8.1. Laboratory surveillance test requirements for adsorbents^a

Activated carbon bed depth	Laboratory test requirements for a representative sample
2 in.; air filtration system designed to operate inside primary containment	Test initially and yearly thereafter under 95% relative humidity, maximum design temperature, and design face velocity for an elemental iodine penetration of <1.0% and <10% for methyl iodide ^b
2 in.; air filtration system designed to operate outside the primary containment, and relative humidity controlled to 70%	Test with methyl iodide initially and yearly thereafter under 70% relative humidity, maximum design temperature, and design face velocity for a penetration of <1.0%.
4, 6, 8, and 15 in.; air filtration system designed to operate outside the primary containment, and relative humidity controlled to 70%	Test with methyl iodide in 2-in. increments initially and semiannually thereafter for the 4-in. bed, every eight months for the 6-in. bed, and annually for the 8- and 15-in. beds under 70% relative humidity, maximum design temperature, and design face velocity for a penetration of <0.175%

^aTest requirements proposed for reissue of Regulatory Guide 1.52, *Design, Testing, and Maintenance Criteria for Atmospheric Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants*, U.S. Atomic Energy Commission, Washington, D.C., 1973.

^bMaximum postulated DBA temperature (°F) rounded to the next highest decade (e.g., 181°F should be rounded to 190°F).

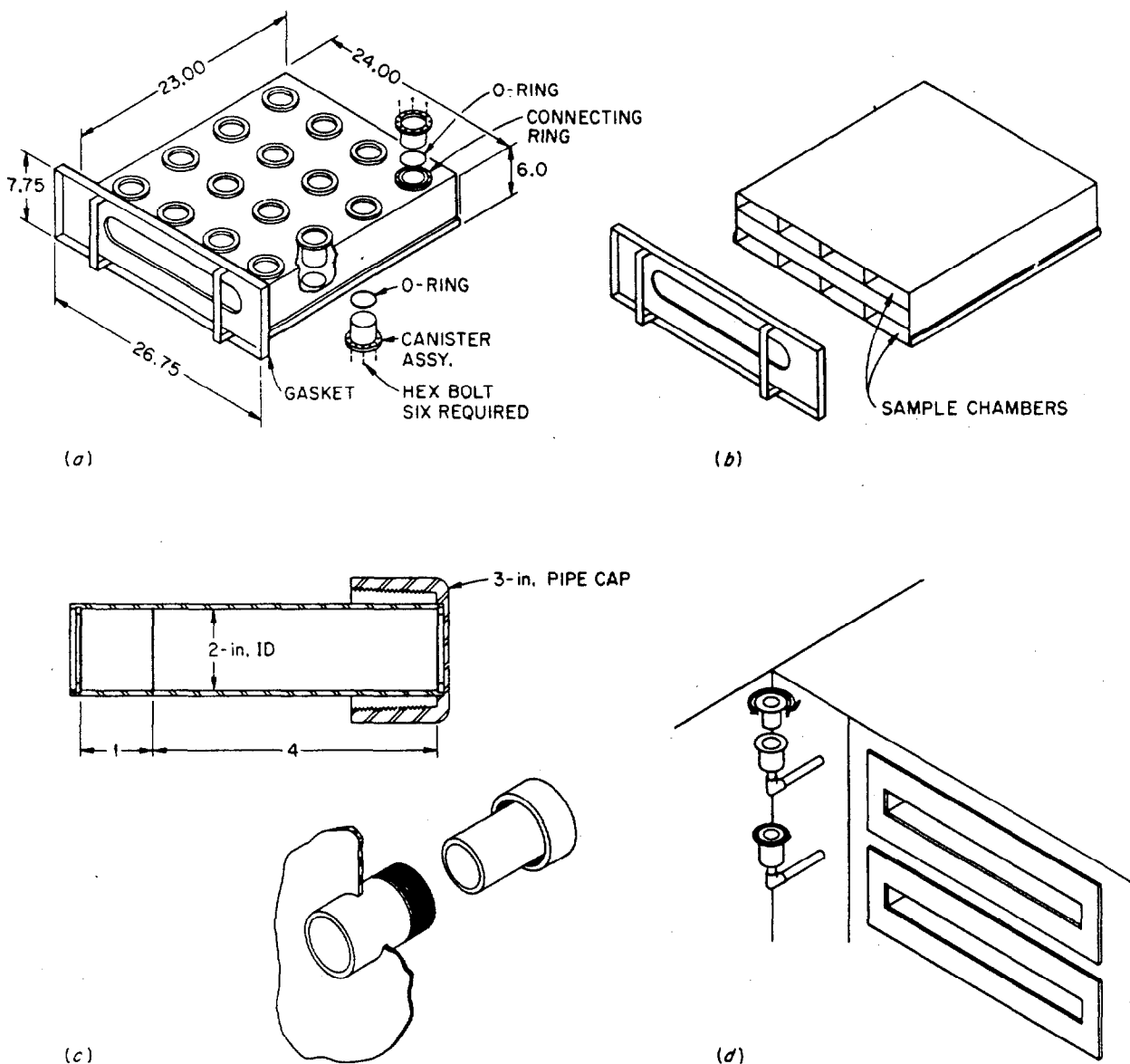
representative as possible, which means that they must have been subjected to the same airflow, temperature, humidity, and poisoning conditions as the remainder of the adsorbent in the same stage. Ideally, a large sample should be taken from a point close to the center of the stage, since this area probably receives the most severe environmental exposure. Such a sample is often not practical because of the difficulty of extracting the sample and of returning the system to its original condition afterwards. Therefore, a number of sample cartridge designs have been developed, a few of which are shown in Fig. 8.21. Sample cartridges must be provided in sufficient number to permit taking samples at specified intervals for the life of the adsorbent. British tests indicated a maximum life of coal-base activated carbon of three years for non-operating or standby systems and 18 months for continuously on-line systems.²³ No guides have been established for the adsorbents used in this country. Sample cartridges must be designed so that bed depth of, airflow through, and pressure drop across the cartridge are essentially the same as for the adsorber stage itself. For this reason, the zero-flow hang-on cartridges shown in Fig. 8.22 are not acceptable. Flow-through cartridges must be provided and installed in an area of the bank where air will flow through them and not in obvious low-flow areas such as the outside edge of the mounting frame. Cartridges must be accessible to service personnel without the necessity of climbing up component banks or bringing in temporary ladders or scaffolding.

If sample cartridges are not provided, other means of sampling are necessary. In a multicell system such as that shown in Fig. 8.23, samples can be obtained by removing and emptying a cell, taking a sample of the loose adsorbent, refilling the cell (using a qualified filling procedure to ensure proper loading), and reinstalling it in the bank. For some PSU adsorbers, it may be possible to take a thief sample²² from a point close to the center of the unit. In small adsorber installations, when considering the cost of the tests, some users have found it more economical to simply replace the adsorbent at the stipulated sampling frequency rather than make surveillance sample tests. (Regulatory Guide 1.52 currently calls for adsorbent testing at intervals of 720 hr of operation until experience shows that longer intervals between testing are justified on the basis of life curves developed from the test results.)³

8.3.5 Frequency of Testing

The following test schedule is suggested for both continuously and intermittently on-line systems designed in accordance with this handbook.

Application	Frequency
All systems	Before system startup, following any major system repair or modification, and following each filter (adsorber) replacement
Radiochemical plants, fuel reprocessing plants, and laboratory fume hoods	Semiannually or quarterly where high moisture loadings or high temperatures are involved. In some systems, frequent (even monthly) testing is often specified where the environment is particularly severe; the frequency may be reduced if experience indicates a lesser frequency is satisfactory
Reactor postaccident cleanup systems and ESF postaccident cleanup systems of fuel reprocessing plants	Annually or 720 hr of system operation, whichever comes first (as specified in Regulatory Guide 1.52)
Zone III contamination areas of facilities handling moderate to large quantities of radioactive materials	Annually
Zone I and II contamination areas of plants and laboratories handling moderate to large quantities of radioactive materials	Annually
Zone IV contamination areas (glove-box lines, hot-cell exhaust, etc.) of laboratories and plants handling moderate to large quantities of radioactive materials	Semiannually unless experience indicates that annual testing is sufficient. If filters (adsorbers) are replaced at short (less than six month) intervals to limit exposure of personnel to radiation during a filter (adsorber) change or to permit contact maintenance of system by limiting the amount of radiation that can be collected in the filters (adsorbers), systems should be in-place (i.e., leak-) tested following each filter (adsorber) change. Laboratory testing of adsorbents may not be necessary if the adsorbent is replaced frequently
Systems continually on standby but operated only occasionally during plant maintenance to ventilate the system	At least biannually



DIMENSIONS ARE INCHES

Fig. 8.21. Typical adsorbent sample canister designs. (a) Special type II cell with 32 sample canisters. One canister is removed and replaced each time a sample is taken (blanking off openings, instead of canister replacement, would result in increasing airflow through remaining canisters). (b) Special type II cell with eight sample chambers. One of eight chambers is emptied and refilled each time a sample is to be taken. (c) Through-wall sample canister for 4-in. deep-bed gasketless adsorber with 1-in. guard bed. Canister fits into pipe nipple, sealed-welded into wall of adsorber unit. Nipple is blanked off or canister is replaced with a new canister each time a sample is taken. (d) Through-mounting-frame test canister installation using sample units of same design shown in (a). Holder is blanked off or refilled with a new sample unit when a sample is taken. Sampler tops in mounting frame should be closer to center of bank to achieve more representative airflow through samples.

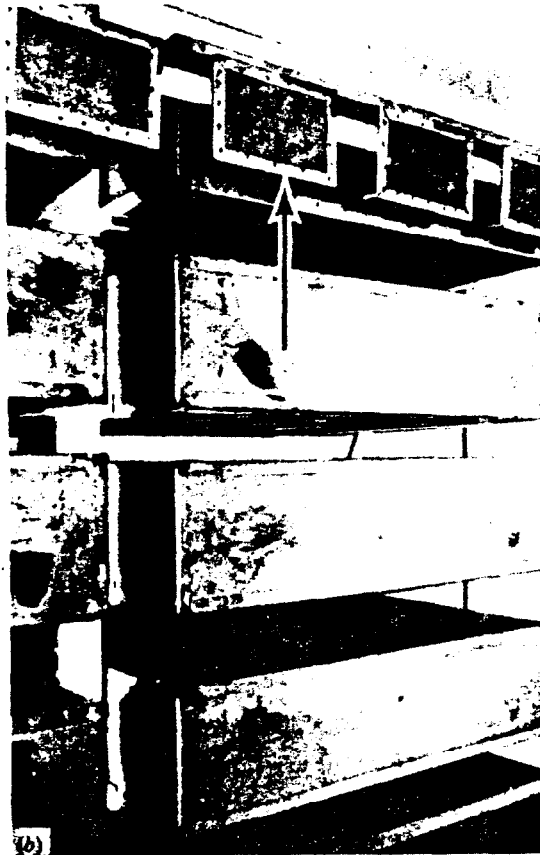
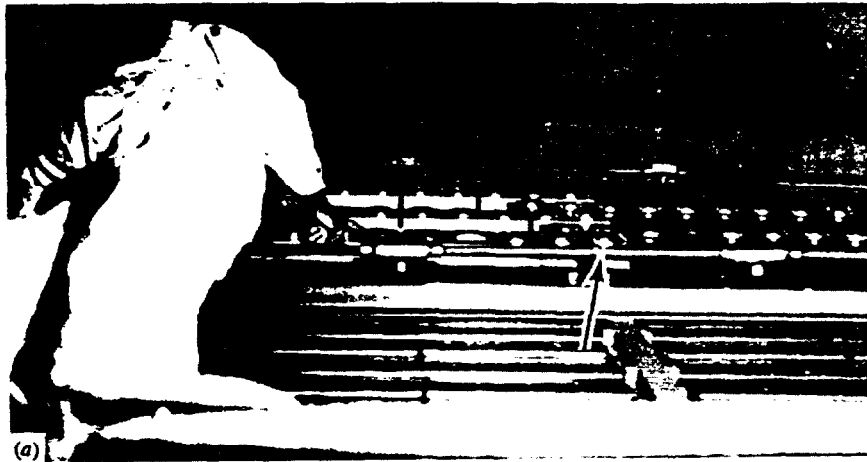


Fig. 8.22. Examples of unacceptable adsorbent sample canister design. Hang-on canisters have no flow through them and do not provide representative samples. (a) Hang-on adsorbent sample canisters suspended upstream of adsorber bank. Note poor access to sample canisters; (b) hang-on adsorbent sample canisters installed upstream of adsorber bank.



Fig. 8.23. Large bank of tray-type (IES CS-8, type II) adsorber cells. Samples can be taken from installations of this type by removing a cell from the center of the bank. The emptied cell is refilled with new adsorbent and replaced prior to making the in-place test. Note lack of a permanently installed access to upper tiers of cells and structural angles in the floor, which represents a stumbling hazard to service personnel.

8.4 VISUAL INSPECTION

Although visual inspection is not an acceptance or surveillance test procedure as such, it is an integral and vital part of every such test. A careful visual examination should be made of each internal and external component prior to installation to verify that the items have been received in satisfactory and serviceable condition. After installation, as part of the acceptance test procedure, the system should be checked to make sure that all required items have been properly installed. A suggested check list of what to look for is given as Appendix A of ANSI N510, *Standard for Testing of Nuclear Air Cleaning*

Systems. Visual inspection will often reveal deficiencies that could cause test failure or invalidate test results. Visual inspection should be made under a combination of background lighting and supplementary lighting that provides at least 100 ft-c on the surfaces being examined. Correctable deficiencies should be recorded together with the remedial action taken. Experience has shown that a record of deficiencies and their method of correction is invaluable for future maintenance of the system, and this practice should be followed in both acceptance and surveillance testing. Errors and deficiencies that cannot be corrected immediately, or that require replacement of an item, should be brought immediately to the attention of responsible authorities.

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